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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2015/2016

ENT4046 – NANO/MICROELECTROMECHANICAL SYSTEMS (N/MEMS)

2 March 2016
9:00 – 11:00 am
(2 Hours)

INSTRUCTION TO STUDENT

1. This examination paper consists of 5 pages with 4 questions only.
2. Answer all questions.
3. Please print all your answers in the Answer Booklet provided.

QUESTION 1

- (a) (i) Define what is a transducer. [1 mark]
(ii) Name the possible energy domains for signal transduction. [3 marks]
(iii) Compare the key characteristic between microelectronics and microsystem, as listed in the Table Q1 below: [4 marks]

Table Q1

Characteristic	Microelectronics	Microsystem
Components		
Throughput		
Structure		
Design		

- (b) (i) With aid a simple diagram, briefly describe what is MEMS as a microsensor. [3 marks]
(ii) With aid a simple diagram, briefly describe the components of a microsystem which is designed for air-bag deployment. [4 marks]
- (c) (i) Name two types of scaling law. [2 marks]
(ii) Based on rigid-body dynamics, calculate the associated changes in the acceleration, time, and power supply to actuate a MEMS component if its weight is reduced by a factor of 10. [4 marks]
(iii) A micromotor is hardly designed to be powered by the electromagnetic force. Please provide a detailed explanation based on the scaling law. [4 marks]

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QUESTION 2

- (a) A resistive ohmic heater is located in the middle of a suspended fixed-fixed cantilever. The beam is made of silicon nitride and the metal leads are made of aluminum. As shown in Figure Q2, the width of the beam is $10\ \mu\text{m}$, $L = 100\ \mu\text{m}$, and the thickness of both aluminum (t_m) and silicon nitride (t_b) is $0.2\ \mu\text{m}$. The thermal conductivity of aluminum and silicon are 240 and $5\ \text{W/mK}$, respectively.

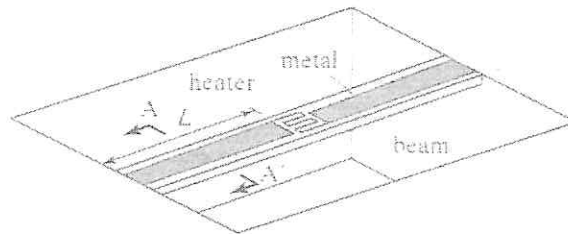


Figure Q2

- (i) Sketch the A-A' cross-section. [3 marks]
- (ii) Find the value of the thermal resistance experienced by the heater. [6 marks]
- (iii) If the total heat flux from ALL resistors is $0.1\ \text{mW}$, what is the temperature difference between the heater and the substrate frame. [4 marks]
- (b) Thermal sensors are useful for radiation detection, especially in the infrared (IR) region. One of the technique to detect IR radiation is based on the photothermal heating by using a heat absorber, which is coupled to a thermal bimetallic cantilever beam.
- (i) Sketch the top-view and the cross-section view of a micro-opto-mechanical, bimetallic cantilever structure for IR sensing [5 marks]
- (ii) With aid a simple diagram, suggest an electrical method for detection of bimetallic displacement. [2 marks]
- (iii) Briefly describe the fabrication of the bimetallic cantilever IR sensor, which consists of a gold layer coated on top of the nitride beam. [5 marks]

Continued...

QUESTION 3

- (a) (i) Define what is a gauge factor for resistive sensing bar. [1 mark]
- (ii) Derive the gauge factor for a resistor under stress. [3 marks]
- (iii) Compare the metal strain gauge and piezoresistive strain gauge. [4 marks]
- (b) A fixed-free cantilever is made of single-crystal silicon. The longitudinal axis of the cantilever has the [100] crystal orientation and made into a resistor by diffusion process with longitudinal gauge factor of 50. The length, width and thickness of the cantilever are given by, respectively, $l = 250 \mu\text{m}$, $w = 25 \mu\text{m}$, and $t = 10 \mu\text{m}$. A force $F = 250 \mu\text{N}$ is applied at the end of the cantilever. Calculate
- (i) sketch the fixed-free cantilever, in particular the doped piezoresistor.
- (ii) the stress σ ($= F/A$), which is uniform throughout the cantilever,
- (iii) the strain, given by $\varepsilon = \sigma/E$, where E is the Young modulus (130 GPa), and
- (iv) the relative change of resistance as a result of the bending. [4 x 3 marks]
- (c) With aid simple diagrams, briefly describe the design and fabrication of a pressure sensor which consists of a deformable diaphragms with four embedded piezoresistors, as strain sensor, in full Wheatstone bridge configuration. Briefly describe the signal processing and output.

[5 marks]

Continued...

QUESTION 4

- (a) (i) With aid a block diagram, provide an overview of the initial design consideration of a microsystem. [5 marks]
- (ii) Name a few design constraints, which may be non-technical or may be related to the marketing of the product. [2 marks]
- (iii) Name the types of materials to be considered. [2 marks]
- (iv) Name the manufacturing processes for producing microdevices. [3 marks]
- (b) (i) What are the three levels of MEMS packaging. [3 marks]
- (ii) What are major reliability issues for the Level (1+2) packaging of MEMS, or microsystem? [2 marks]
- (iii) Briefly describe what are the four reasons for high cost of microsystem packaging. [4 marks]
- (c) Suggest the common materials required for microsystem packaging as listed in Table Q4 below: [4 marks]

Table Q4

Microsystem Components	Available Materials
Die	
Insulators	
Die Bonding	
Wire Bonding	

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